THE STATISTICAL INTERPRETATION OF SIMULATED EMERGENCY BRAKING EVENT TIME SERIES DATA

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ABSTRACT

Over three hundred four-second / 40hz time series datasets (from simulated emergency braking manoeuvres at English fatal accident sites and field trials) (see Fig 1) were classified using key characteristics of the braking sequences extracted for each event. These characteristics were then tested for significant difference between road surface types and braking system types. One key marker, average deceleration, was also compared against existing benchmark 'typical' values for acceptable performance as found in the literature.

The views expressed in this Paper are those of the Author.

1 INTRODUCTION

During the course of the investigation of a fatal or near-fatal road traffic accident (RTA) occurring in the UK, tests may be undertaken by qualified Police collision investigators to quantify the frictional properties of the road surface at the scene. The fundamental physics behind the test methodology was first tested in court in the 1940's [1].

Fig 1: The diverse range of vehicles contributing to the database of deceleration ('skid') tests

These tests are commonly carried out using equivalent vehicles if those involved in the collision cannot be used. The momentary accelerations and decelerations of the vehicle during a simulated emergency braking manoeuvre ('skid test') undertaken at the scene are recorded using a device equipped with an accelerometer and a timing circuit. The data so recorded is typically presented to the collision investigator in the form of two summary statistics: average and maximum deceleration during the skid test. The average deceleration is often compared against what the collision investigator personally considers to be 'typical' and any departure commented upon accordingly in subsequent accident reports. The average value can be used in reconstruction formulae.

Data recorded at the scene of a a number of fatal and/or near fatal RTAs were collected for this study, with the support of a number of Police forces around England, these tests were classified using the BRAKING STATE of the tests: (with ABS [Anti-Blockieren System / Anti-lock Braking] or without ABS, [NoABS, where the tyres can lock then slide on the road surface]), the SURFACE TYPES (see Fig 2) were either traditional POSITIVE TEXTURE (PTS) surfaces such as Hot Rolled Asphalt and Surface Dressing or the more recently adopted NEGATIVE TEXTURE (NTS) surfaces such as Stone Mastic Asphalt (SMA) , the SURFACE STATE was recorded as WET or DRY.

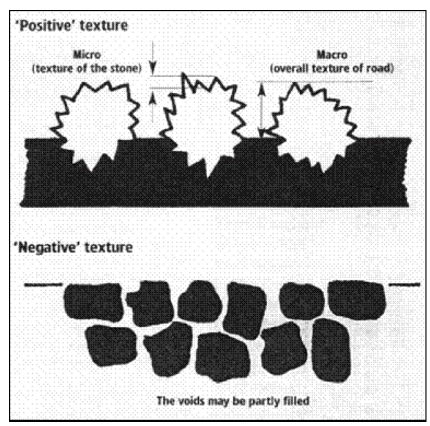


Fig 2 Idealized negative and positive textures [2]

As tests were more commonly undertaken on DRY surfaces, the great majority of tests fortunately fell within the group of DRY tests required for the PhD study.

It should be noted that road surface frictional conditions (not caused by ice or snow etc) were not a

significant contributory factor in any personal injury RTAs in the UK [3].

2 EXTRACTING DETAILED DATA

Interrogation of the time series of momentary accelerations or decelerations used to derive the summary statistics were expected to provide useful information with respect to the behaviour of the road surface when interacting with the tyres of vehicles either with ABS or without ABS (NoABS).

Two decelerometer devices are in common police use in the UK: the Turnkey Instruments Skidman (known as Brakesafe when equipped with a test speed output) and the Vericom Computers VC series [4]. The internally calculated AVERAGE and MAXIMUM decelerations downloaded from the Skidman device (40hz data) using the manufacturers software (Skidcalc) were shown in the course of this analysis to correspond to a moving average of 8 or 9 adjacent readings, whereas the Vericom device downloads (100hz data) using the Vericom Profile package returns the true momentary values from the accelerometer. This difference has little impact with respect to average deceleration but significantly lowers the maximum values retrieved.

For the purpose of this study, the momentary data from Skidman tests was retrieved using a DOS package (SIMRET) and a download cable (as used with Skidcalc), these momentary readings were downloaded in CSV format and then transposed and combined into a single database (one row per test, up to 253 readings per test).

3 IDENTIFYING KEY DATAPOINTS IN THE TIMESERIES DATA

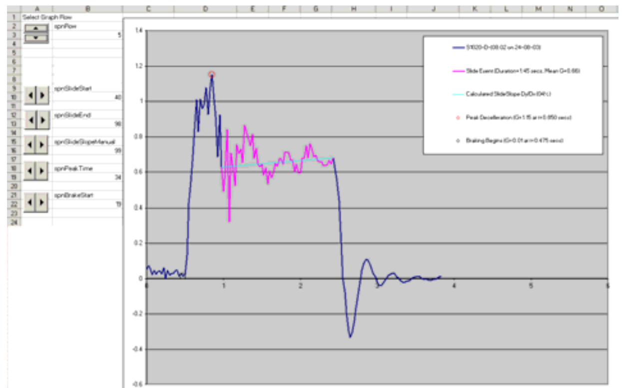
The literature regarding the interpretation of skid test results has identified the maximum and average decelerations as key parameters of interest [5, 6]. The viewing of the time series as graphs in Microsoft Excel enabled other key features to be identified in addition to the maximum and average decelerations.

A Microsoft Excel Visual Basic macro (The ‘classification macro’) was also developed to enable ‘tags’ to be placed on specific points in the time series (via the use of spin box functionality in Visual Basic) to enable further calculations to be undertaken via the integration of the decelerations between specified limits and via the tabulation of the ‘tagged’ key points. A typical screenshot is shown in Fig 3.

The following points were extracted tabulated using the ‘classification ’ macro’:

1. Start of braking
2. ABS maximum deceleration
3. NoABS maximum deceleration before sliding phase
4. NoABS Start of sliding phase (associated with onset of wheel lock)
5. NoABS End of sliding phase
6. End of braking / Start of Suspension Bounce

These points were also highlighted on the deceleration graph in question as a circle on a point.



IO	IP	IQ	IR	IS	IT	IU	IV
BrakeStartFound	PeakTime	PeakTimeG	SlideStartTime	SlideEndTime	SlideAvg	SlideDur	SlideSlope
17	35	1.021	42	123	0.616098		
19	33	0.961	40	123	0.621119		
19	36	1.027	48	101	0.687648		
19	34	1.152	40	98	0.663576		
10	47	1.133	61	116	0.605696		

Fig 3 Screen shots of the “Classification Macro”

Any time interval between these points could then be calculated, the individual decelerations could be integrated (to derive average deceleration during braking) and the average and maximum decelerations derived from the data could be compared against those calculated internally by the device.

The relatively small number of tests on WET surfaces led to a decision to focus on DRY tests for the subsequent analysis.

4 DIFFERENCES BETWEEN INTERNAL AND POST TEST AVERAGE AND MAXIMUM DECELERATION

By integrating the momentary decelerations during braking in the time series it is possible to establish the average deceleration for comparison against the internally calculated average values generated by the Skidman at the time of the test.

A consistent under-measurement of the peak deceleration when calculated internally by the Skidman against the average values from the Skidman was seen whereas the internally generated and extracted peak values from the

Vericom VC3000 DAQ device compared well. This discovery is only of interest to those likely to have an interest in peak deceleration; such a group may be those studying critical speed behaviour (the behaviour of vehicles at the point of loss of control during cornering manoeuvres [7]).

5 INITIAL INTERPRETATION OF EXTRACTED DATA

It was anticipated that variations would exist between DRY tests with the same SURFACE TYPE and BRAKING STATE combination, as a result of the variation between vehicle braking systems, tyre compounds and driver technique, and such variation had already been described in the literature *[8]*, thus simple box plots showing the distribution of average deceleration against Police Force were generated in SPSS to aid the initial interpretation of the DRY test dataset between ABS and NoABS tests. (See *Fig 4*). These common characteristics for AVERAGE deceleration between SURFACE TYPE and BRAKING STATE were seen to exist between these force-by-force plots despite the spread:

(i) ABS NTS > ABS PTS (typically)
(ii) NoABS PTS > NoABS NTS (typically)
(iii) ABS > NoABS (typically)

No such trends existed for MAXIMUM deceleration (plot not shown). Since average deceleration trends could be so easily defined visually from the data, key values from the individual tests were simply analysed statistically using T tests in MiniTAB 14 to quantify any significant differences. With the visible trends seen in the box plots between ABS and NO ABS braking in combination with NTS and PTS surfaces there was no real requirement for complex statistical analysis and a simple T test of difference would provide a numerical measure of the differences seen between SURFACE TYPE and BRAKING STATE

6 STATISTICAL DIFFERENCES BETWEEN SUBSETS

The statistical comparisons undertaken identified very significant differences between the average deceleration measured with NoABS braking between NTS and PTS surfaces, as expected ABS braking performed significantly better on both DRY PTS and DRY NTS

Since NOABS braking is likely to deliver higher peak deceleration before wheel lock whereas ABS systems aim to prevent wheel lock, the significantly higher MAXIMUM decelerations for NoABS test is not unexpected.

Table 1 summarises the output of multiple T tests undertaken in MiniTab 14

AVERAGE Deceleration (SlideG) DRY SURFACES				
Sig. diff. (>99%)	ABS NEG	ABS POS	NOABS NEG	NOABS POS
ABS NEG	X	X	**ABS Higher**	X
ABS POS	**NEG Higher**	X	X	**ABS Higher**
NOABS NEG	X	X	X	X
NOABS POS	X	X	**NEG Lower**	X

MAXIMUM Deceleration (PeakG) DRY SURFACE				
Sig. diff. (>99%)	ABS NEG	ABS POS	NOABS NEG	NOABS POS
ABS NEG	X	X	**ABS Lower**	X
ABS POS	**NO DIFF**	X	X	**ABS Lower**
NOABS NEG	X	X	X	X
NOABS POS	X	X	**NO DIFF**	X

Table 1 Summary of T Test results on DRY ROAD tests

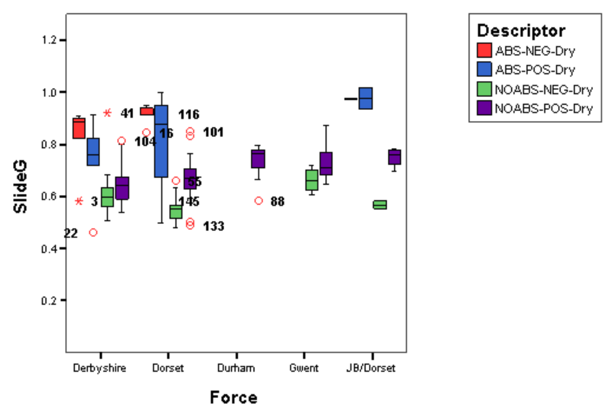


Fig 4: Distribution of Average (Slide) deceleration between Police Forces

7 OBSERVATIONS

The use of the Visual Basic classification macro enables complex time series data to be visualised and key values easily recorded and extracted for use in subsequent analysis. From the perspective of the key aims of the PhD study, the highly significant difference seen in the lower average deceleration with NoABS braking (see Fig 4) on NTS when compared against PTS surfaces supports similar findings in the literature [9, 10] as regards the typically poorer performance on NTS under NoABS emergency braking.

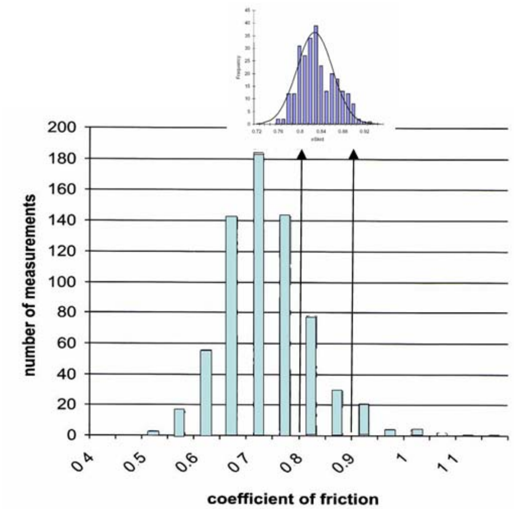


Figure 5: Distribution of Typical Southern UK Values of Dry Friction [11] compared against that given in Goudie et al [12]

8 CONCLUSIONS

Tabulation of data extracted from time series decelerometer records have confirmed that NoABS simulated emergency braking on NTS surfaces delivers a significantly lower level of average deceleration than for NoABS tests on PTS or ABS tests on PTS or NTS. These values are also typically below (05-0.7) those considered typical for dry road surfaces (0.75 – 0.85) (See Figure 5). Tabulation of data extracted from time series decelerometer records have also confirmed that the internally calculated values of average and maximum deceleration generated by the Skidman device are smoothed and in the case of maximum values, typically an underestimate of the momentary maximum deceleration.

9 ACKNOWLEDGEMENTS

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